

STATE OF CALIFORNIA
DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

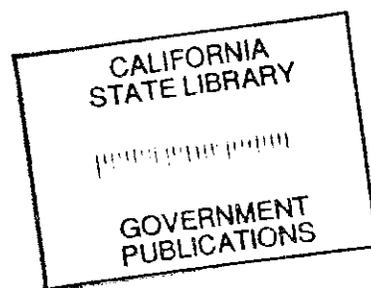
1956 REPORT ON
COOPERATIVE STUDY PROGRAM

WATER USE AND WATER RIGHTS ALONG
SACRAMENTO RIVER AND IN SACRAMENTO-
SAN JOAQUIN DELTA

By

United States Department of the Interior, Bureau of Reclamation
Department of Water Resources, Division of Resources Planning
Sacramento River and Delta Water Association

VOLUME I



GOODWIN J. KNIGHT
Governor



HARVEY O. BANKS
Director of Water Resources

MARCH 1957

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LETTER OF TRANSMITTAL

Sacramento, California
March 1, 1957

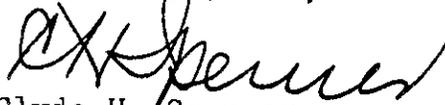
The Diverters of Water Along the Sacramento River
and in the Delta

Gentlemen:

The attached publication entitled "Report on 1956 Cooperative Study Program, Water Use and Water Rights Along Sacramento River and in Sacramento-San Joaquin Delta" is presented for your information and use. This report has been prepared through the cooperative effort of the United States Bureau of Reclamation, the California State Department of Water Resources, and the Sacramento River and Delta Water Association.

It is believed that the information contained in this report will be useful in negotiations aimed at reaching an agreement on water rights along the Sacramento River and in the Delta. The Bureau of Reclamation and the Department of Water Resources will make available the services of their respective staffs for consultation or for the provision of data and information as required prior to and during negotiations.

Very truly yours,



Clyde H. Spencer
Regional Director, Region 2
United States Bureau of Reclamation



Harvey O. Banks
Director of Water Resources
State of California



W. H. Baber
President
Sacramento River and Delta Water
Association

ORGANIZATION
BUREAU OF RECLAMATION
REGION 2, SACRAMENTO, CALIFORNIA

Clyde H. Spencer Regional Director
Ivan P. Head . . . Chief, Regional Project Development Division

Supervisor of activities covered by this report

Leland K. Hill Chief, Water Rights Engineering Branch

Assisted by

John M. Schaser Hydraulic Engineer

and

Jake Osoffsky Chief, Hydrology Branch
Herbert W. Finke Hydraulic Engineer
Howard E. Wittig Hydraulic Engineer
Theodore B. Kukkola Hydraulic Engineer
Hugh A. Pennebaker Hydraulic Engineer
Edward V. Rawlings General Engineer
John F. Mathews General Engineer
William D. Koogle General Engineer

ORGANIZATION

STATE DEPARTMENT OF WATER RESOURCES
DIVISION OF RESOURCES PLANNING

Harvey O. Banks Director of water Resources
M. J. Shelton Deputy Director of Water Resources
William L. Berry Chief, Division of Resources Planning
Carl B. Meyer Chief, Special Activities Branch

Supervisor of activities covered by this report

Wayne MacRostie Principal Hydraulic Engineer

assisted by

Roger R. Lindholm Associate Civil Engineer

and

George W. Deatherage Assistant Hydraulic Engineer
Walter H. Fisher, Jr. Assistant Hydraulic Engineer

Computations were performed by

Bruce J. Baker Engineering Aid II
Fred O. Swanson Engineering Aid II
Paul Garcia Engineering Aid I
Darryl C. McCalister Engineering Aid I

Delineation

John L. James Supervisor of Drafting Services
Carroll L. Emery Senior Delineator
Betty Quan Senior Delineator
Eugene A. Flagler Delineator
William G. McKane Delineator
Kay Shibata Delineator
Mary Stafford Delineator

Adminstration

F. James Murphy . Acting Chief of the Division of Administration
Isabel C. Nessler Coordinator of Reports

ORGANIZATION

SACRAMENTO RIVER AND DELTA WATER ASSOCIATION

Officers and members

- W. H. Baber President
Llano Seco Rancho, Chico
- C. D. Bouton Vice-President
Sutter Mutual Water Company, Robbins
- W. R. Darsie Vice-President
Reclamation District No. 3, Walnut Grove
- Lorris Lauppe Treasurer
Natomas Central Mutual Water Company, Sacramento
- John M. Luther Manager
Sacramento River and Delta Water Association, Sacramento
- Mrs. Aileen B. Armstrong Grimes
H. H. Balsdon Reclamation District No. 108, Grimes
Levi Bentz Chico
C. A. Bielefeld Reclamation District No. 999, Clarksburg
J. L. Browning Colusa
Oscar N. Burroughs Cloverleaf Farms, Knightsen
Harold A. Butcher East Contra Costa Irrigation District, Brentwood
G. C. Carter M. and T., Incorporated, Chico
Dick Carstenbrook Tisdale Irrigation and Drainage
Company, Meridian
- E. N. Cook Reclamation District No. 1004, Colusa
Peter Cook, Jr. Reclamation District No. 2084, Rio Vista
William Crawford Sutter Mutual Water Company, Pebble Beach
Fred L. Dambacher Reclamation District No. 556, Walnut Grove
Miss Olive Percy Davis Sebia Davis Estate, Sycamore
Philip F. Driver Reclamation District No. 1002, Sacramento
Robert L. Essick Newhall Land and Farming Company, Meridian
Walter Eittle Meridian
R. D. Goodwin California Packing Corporation,
Hastings Tract and Union Island
- Joe Green Reclamation District No. 551, Courtland
J. D. Hall Fremont Irrigation Company, Tracy
Wayne E. Hall Meridian
John R. Henle Woodland
R. J. Heringer Reclamation District No. 150, Clarksburg
Miss Evelyn Holland River Farms Company of California,
Knights Landing
- Arthur C. Huston, Jr. Woodland
W. T. Jarrett Liberty Farms Company, Liberty Farms
Albert M. Jongeneel Reclamation District No. 501, Walnut Grove
Emilio Lagomarsino Reclamation District No. 2041, Stockton
Lamb Bros. Knights Landing
Frank Lamb Sutter Mutual Water Company, Knights Landing

J. R. Lauritzen Reclamation District No. 1601, Rio Vista
 Gordon J. Leiser Knights
 Douglas McCormack Rio Vista
 Wallace McCormack Reclamation District No. 341, Rio Vista
 S. Atwood McKeehan. Butte Slough Irrigation Company, Ltd., Marysville
 Gus Olson Reclamation District No. 999, Clarksburg
 Frank S. Reager, Jr. Glenn
 Mrs. Elizabeth M. Reimer Colusa
 Terrill Sartain Reclamation District No. 1004, Colusa
 B. K. Schorr Rose Orchard, Bryte
 William S. Towne Staten Island Land Company, Staten Island
 A. Darwin Tuttle Tuttle Land Company, Colusa
 Charles W. Tuttle, Jr. Colusa
 Charles B. Weeks. East Contra Costa Irrigation District, Brentwood
 Miss Alice E. West Sacramento
 John F. Wilcox Reclamation District No. 2067, Rio Vista
 L. D. Wood Woodland Farms, Inc., Woodland
 Horace B. Wulff Reclamation District No. 108, Sacramento

Engineers

Prior to December 5, 1956, the Association retained the firm of Bleifuss, Greenwood and Hostetter, Consulting Engineers, and subsequent to January 1, 1957, the Association retained the firm of Bleifuss, Hostetter and Associates (Incorporated).

Supervisor of activities covered by this report

L. A. Hostetter Civil Engineer

assisted by

K. B. Mayo Civil Engineer

Subsequent to January 1, 1957, the Association also retained:

Gerald H. Jones Consulting Engineer

Foreword

This report covering water use and water rights along the Sacramento River and in the Sacramento-San Joaquin Delta, presents the results of a cooperative effort among engineers representing the United States Bureau of Reclamation, the California State Department of Water Resources, and the Sacramento River and Delta Water Association. Each group has contributed substantially through the making of decisions as to technical details of the work and through actual performance of the comprehensive computations involved in these studies. These engineers have agreed upon the basic hydrology, water right assumptions used in the studies, and computation procedures by which the results were achieved. In many cases certain assumptions were suggested by one or more of the parties in order that the information desired by those parties might be obtained and the agreement by the remaining parties to participate in studies of such assumptions demonstrates their willingness to cooperate in the development of all pertinent facts.

The cooperating engineering group wishes to emphasize that water right assumptions made for study purposes may differ considerably from the rights as they might be determined by a court of law. The purpose of these assumptions was to demonstrate the effect of variation of water right criteria on the yields of the water rights and on amounts of supplemental water required to firm up the yields to meet the 1954 or 1955 level of diversions.

The purpose of this report is to present a summary of information believed to be essential for commencing negotiations that will be aimed at reaching an agreement on water rights along the Sacramento River and in the Delta. It is anticipated that there will be many questions left unanswered by this report. However, the findings presented herein will provide a basis for evaluating the relative importance of alternative assumptions as to water rights. Those that appear worthy of further study may be used in additional computations as the negotiations proceed.

Information in this report is presented in two volumes. Volume I contains brief descriptions of the methods and summaries of the findings of the various analyses under the 1956 Cooperative Study Program. Volume II contains 606 tables which present in detail the salient results of the studies.

Basic data and detailed explanations of assumptions and methods used in the studies described in this report, as well as results not shown herein, will be made available for limited distribution at a later date. Original copies of supporting data and computations are filed in the office of the Department of Water Resources in Sacramento.

I - INTRODUCTION

The question as to the relative rights of water users along the Sacramento River and in the Sacramento-San Joaquin Delta has long been a significant one in the affairs of this region. As early as 1920 there was indication of an inadequate water supply to satisfy all water requirements in summer months along the river. In that year the City of Antioch sought an injunction to prevent appropriators of water from the Sacramento River from reducing the flow past the City of Sacramento below 3,500 cubic feet per second so as to prevent impairment of the quality of water available for diversion by the City of Antioch. A temporary injunction was ordered by the superior court, but the order was reversed by the Supreme Court of the State of California. This was followed by the filing of a similar action by the Holland Land Company and other water users in the Delta against the Williams Irrigation District and other upstream interests. However, this case was never brought to trial.

The dry year of 1924 caused serious concern among water users in the area and led to the first Sacramento-San Joaquin River problems conference held in that year. This conference resulted in an agreement whereby the water users pledged to exercise their respective rights to the use of water in such a manner as to accomplish the maximum degree of water conservation. The Sacramento-San Joaquin Water Supervisor was appointed in the State Engineer's staff as a result of this conference in order that a record of the diversions and streamflow might be obtained and in order

to promote maximum conservation of water. The water superintendent's staff was again called upon to assist in prevention of waste of water during the critical year of 1931. However, it was apparent that this method alone would not solve the problem with respect to the Delta and that a more positive limitation of upstream diversions in accordance with water right criteria would be necessary if the Delta were to get its share of the water supply.

Members of the staff of the State Engineer's office recognized as early as 1924 that the Sacramento River was over-appropriated at that time with respect to low flow conditions that occur in such critical years as 1924. It was also recognized that the only solution to this situation was the construction of projects which would store water in months of surplus runoff and release it for use during the summer months. This fact was an important consideration in the recommendation by the staff of the Division of Water Resources for implementation of The State Water Plan presented to the Legislature in 1931. In 1927, anticipating the presentation of this plan, the Department of Finance of the State of California filed upon unappropriated waters of the Sacramento River and other major tributaries of the Central Valley in order that water rights might be obtained to permit such storage of surplus water.

Although it was contemplated that the Central Valley Project, the initial unit of The State Water Plan, would be built by the State of California, it was found necessary to call upon the Federal Government for assistance in implementing this project. As a result, the United States Bureau of Reclamation commenced construction of the Central Valley Project in 1937. Applications for

water rights that had been filed by the State Department of Finance in 1927 were assigned to the United States for project purposes. In addition the State Department of Finance filed supplemental applications required for Central Valley Project operation in 1938 and these filings were also assigned to the United States. Subsequently the Bureau of Reclamation made independent application for water rights for its Central Valley Project. The present status of these water right applications held by the Bureau of Reclamation is that they have been protested by various parties along the Sacramento River and in the Delta, and action granting permits is being withheld pending the outcome of current negotiations which this report is designed to assist.

Subsequent to 1944 the Bureau of Reclamation began to interview diverters along the Sacramento River with the view of attempting to settle the water rights problem. Results of the interviews and exchange of correspondence with individuals and with water user organizations appeared to indicate that such attempts would be fruitless. Subsequently it became the conviction of many persons involved in the water rights problem that litigation would be required in order to determine the various water right priorities and quantitative entitlements thereunder including the priority of the right of the United States to divert and store water for purposes of the Central Valley Project.

This fact was called to the attention of various leaders in the Congress and the State Legislature and the result was the so-called "Engle Committee Hearing."* At this hearing apprehension

*Hearings at Sacramento, California, before a Special Subcommittee on Irrigation and Reclamation of the Committee on Interior and Insular Affairs, House of Representatives, 82nd Congress, 1st Session, and a Joint Interim Committee on Water Problems of the California State Legislature on Central Valley Project, California, Water Rights, Supplies and Uses, October 29, 30, 31, 1951.

was expressed by representatives of the water users, by State Legislators, and by Congressmen in attendance as to the complexities, expense and time that would be involved in a lawsuit of the magnitude required to settle the water right problems along the Sacramento River and in the Delta. It was the general conclusion of the hearing that a lawsuit should be avoided if at all possible and that a practical operating agreement should be obtained by negotiation.

Memorandum of Understanding

Subsequent to the Engle Committee Hearing, an exchange of correspondence took place between the Secretary of the Interior and the Governor of California to discuss the means by which the rights of various claimants to use of water along the Sacramento River and in the Delta might be settled by negotiation. As a result, the Governor arranged a series of conferences among the various claimants to the waters involved which led to the execution on July 7, 1952, of the "Memorandum of Understanding Relating to a General Approach to Negotiations for Settlement of Water Diversions from the Sacramento River and Sacramento-San Joaquin Delta with the Objective of Avoiding Litigation." The parties who signed this agreement were the Bureau of Reclamation, the Sacramento Valley Water Users Committee and the Division of Water Resources of the State of California. A copy of the Memorandum of Understanding is presented in Appendix A. Under this memorandum the parties did not guarantee a final agreement, but they did "agree to explore the full ramifications of the approach, with good faith and with hope of agreement".

Trial Distribution Agreements

Further negotiations among the water users, the Bureau of Reclamation, and the State Engineer, pursuant to the general approach set forth in the Memorandum of Understanding, resulted in the "Agreement for Trial Distribution of Water of the Sacramento River during 1954" and the "Sacramento River and Delta Trial Water Distribution Agreement for 1955." Copies of these agreements are presented in Appendixes B and C, respectively.

These agreements provided for a substantial increase in the scope of hydrographic measurements within the service area of the Sacramento River and Delta and for a number of analyses pertaining to data gathered during the Trial Distribution Program and to data available as a result of earlier hydrographic measurements by the State and by agencies of the Federal Government. Monthly reports of hydrographic data accumulated on a current basis were submitted by the State Engineer for the months of March through October in the years 1954 and 1955. In addition summary reports entitled "Sacramento River Trial Water Distribution 1954, Summary Report of Data" dated December 1954, and "Sacramento River and Sacramento-San Joaquin Delta Trial Water Distribution 1955, Summary Report of Data" dated January 1956 were prepared by the State Engineer. A report entitled "Sacramento River and Sacramento-San Joaquin Delta Trial Water Distribution 1954 Report of Analyses" dated April 1955 was also submitted as a result of the studies pursuant to the 1954 agreement.

There was a series of conferences among representatives of the water users, the Bureau of Reclamation, and the State Engineer, which took place in the fall of 1955 and the early part of 1956. The

consensus of these conferences was that sufficient data or physical facts were available to permit final computations of the water rights information which the conferees agreed should form the basis for negotiation of a water rights settlement. They believed that such negotiations should take place as early as possible. Specifically, it was thought essential that the studies include consideration of water rights which had not been taken into account in earlier trial distribution studies. Consequently, on May 14, 1956, engineer representatives from the then State Engineer's office began the work program in cooperation with the consulting engineer for the Sacramento River and Delta Water Association. Following a meeting on May 23, 1956, the United States Bureau of Reclamation designated engineering personnel to participate in this program on its behalf. This work has been designated the "1956 Cooperative Study Program."

Scope of 1956 Cooperative Study Program

Data on stream flows, diversions and return flows available from records of the United States Geological Survey and of the water supervision activity of the Department of Water Resources were used as a basis for estimating various facts relating to water right claims along the Sacramento River and in the Sacramento-San Joaquin Delta. Estimates were made of modified natural flows that would have existed at the major gaging stations along the Sacramento River and at other points if diversions from the river had not been made, but if certain assumed diversions from tributaries to the river and to the Delta had been made. These estimates pertained to the months of April through October from 1924 through 1954. Determinations of lands physically riparian to the Sacramento River upstream from

Sacramento made by the Bureau of Reclamation on the basis of detailed title searches were spot-checked to satisfy the other participating engineering representatives that the methods used were reasonable and accurate. These determinations included estimates of the net areas of riparian lands that have been irrigated historically and of those lands susceptible of irrigation by reason of their topography and soil quality. Information on appropriative water rights was tabulated from the files of the State Water Rights Board for those appropriations initiated subsequent to the Water Commission Act of 1914. Information on appropriations initiated prior to the effective date of that act was obtained and assumptions were made as to the portions of such water right claims that have been vested by reason of beneficial use. Estimations originally made by the Bureau of Reclamation of the extent of overlap between lands covered by appropriative water rights and physically riparian lands were spot-checked in order to confirm the method used and to permit an assumption of its accuracy. Studies had been made by the Bureau of Reclamation to determine areas irrigated historically that were neither physically riparian nor covered by appropriative water rights. These estimates were checked under the cooperative study program. Tabulations of assumed water rights for purposes of studies were made from the foregoing information on a monthly basis under assumed demand schedules. Estimates of modified natural flows and assumed entitlements under various water rights were used to estimate the yields of those rights, the deficiencies or differences between the yields and the 1954 or 1955 level of diversion, and requirements for supplemental water. Other information such as water remaining at various points in the

Sacramento River and in the Delta after satisfaction of water rights of various priority was also computed. Tabulations of information estimated by the various studies are presented in Volume II of this report.

Information on water right yields, deficiencies, and supplemental water requirements were used by the engineers representing the Department of Water Resources to arrive at a number of possible alternative allocations of responsibility for payment for supplemental water among individual major entities. The division of responsibility for salinity control, which is essential to water utilization within the Delta and for exportation from the Delta, was also considered. Findings of these studies and discussion thereof are presented as Chapter VI of this report.

Not considered in this discussion of allocation of responsibility for payment are actual monetary considerations that might be involved by reason of the unit cost of supplemental water. Furthermore, no consideration is given in these studies to the capability of the Central Valley Project to meet the level of local diversions corresponding to the 1954 or 1955 condition which is assumed in the water deficiency and supplemental water requirement studies. However, it is generally considered that the project is capable of supplying at least that level of local water utilization provided appropriate deficiencies are taken in critically dry years such as 1924, 1931, and 1934.

Area of Investigation

The area covered by the 1956 Cooperative Study Program is shown on Plate 1, entitled "Location of Sacramento River-Delta Service Area." This area comprises roughly 1,600,000 acres, of which approximately 900,000 acres are north of the latitude of Sacramento and approximately 700,000 acres are in the Delta. In 1954, approximately 325,000 acres of that portion north of Sacramento were irrigated by direct diversion from the river, and in 1955 about 520,000 acres were irrigated in the Delta. Those are the years when detailed land use surveys were made by the State in the respective areas.

Within this general service area an extensive agricultural industry is located. There are many varieties of orchard, truck, and field crops, but north of Sacramento the major crop for many years has been rice. In 1954, the year of maximum planting of that crop, about 185,000 acres of the aforesaid area irrigated from the river was planted to rice alone. "Grain and hay" was the major crop group in the Delta in 1955, covering about 96,000 acres. Important urban areas within the Sacramento River service area are the Cities of Redding and Sacramento. The City of Red Bluff is also within this service area, and its industrial significance has taken on added stature in recent years.

The source of the major water supply available to this area is the snow deposited upon the mountains of the Sierra Nevada and Cascade Ranges during winter months. The melting snow in the course of the season provides the water supplies of the Sacramento, Feather, American, Mokelumne, and San Joaquin Rivers and other minor tributaries. However, the largest part of the runoff occurs in the

winter, spring, and early summer months, and a relatively small amount occurs during late summer and early fall months when water is required for large irrigation demands. Shasta Reservoir on the Sacramento River north of Redding, Lake Almanor on the Feather River, and Folsom Reservoir on the American River are the largest of the artificial storage units that have been provided to store winter and spring runoff in order that it may be available for summer irrigation and for generation of hydroelectric power.

Water requirements in the Sacramento River-Delta service area are of a number of different types, but the most important of these is the irrigation requirement. Diversions from the Sacramento River north of the City of Sacramento in 1954, the year of maximum diversions, amounted to approximately, 2,088,000 acre-feet during the seven-month irrigation season from April through October. Consumptive use in the Sacramento-San Joaquin Delta Lowlands from April through October was estimated on the basis of a 1955 land use survey to be approximately 1,059,000 acre-feet. Diversions to the Delta Uplands in 1955 totaled about 385,000 acre-feet during the same months. Neglecting the fact that one of the foregoing quantities is a consumptive use value and that the remainder are gross diversions, the water utilization totals approximately 3,532,000 acre-feet during the seven-month irrigation season. Also, over 1,000,000 acre-feet are presently being exported annually from the Delta through facilities of the Central Valley Project and of the City of Vallejo. Of the foregoing quantities, requirements for municipal and industrial use amount to in the order of only one per cent of the totals.

Other recognized requirements for water in the Sacramento River-Delta service area are the substantial requirements for salinity control necessary to prevent water in the channels of the Delta from being degraded by salt water from Suisun Bay, requirements for navigation to allow barge traffic between Knights Landing and the vicinity of Colusa, requirements for protection and propagation of fish life below the major reservoirs of the Central Valley Project and requirements for power generation incidental to the other primary water requirements.

II - MODIFIED NATURAL FLOWS

The first step in studies of the yields of assumed water rights along the Sacramento River and in the Delta was the estimation of modified natural flows at various points. Modified natural flows, as defined for use in these studies, comprise flows that would have existed without diversions from the Sacramento River but with historical impairment or with impairment at an assumed present level of diversions on tributaries either to the Sacramento River or to channels of the Delta. It was also defined to include those flows that would have existed without regulation by Shasta or Folsom Reservoirs.

Methods of Estimation

Modified natural flows of the Sacramento River were estimated for points (1) at Shasta Dam, (2) above the mouth of Colusa Basin Drain near Knights Landing, taken as the point of minimum flow during the irrigation season, and (3) above the mouth of the American River, assumed to be a point of inflow to the Delta. Additional modified natural flows available to the Delta were taken to be historical flows of all other Delta tributaries. A further allowance was included for return flow from diversions to the Delta Uplands at the 1955 level. Also estimated were quantities of modified natural flows of the Sacramento River at Red Bluff, Butte City, Colusa, Wilkins Slough, Knights Landing, and Verona, but these were not used in studies described hereinafter. Values of modified natural flows were estimated or taken from records for the period April through October of each year from 1924 through 1954.

The months of November through March were excluded from the study period because sufficient flows were found to exist during those months to satisfy all assumed local rights along the Sacramento River and in the Delta except during critically dry years. Local water rights are defined as all rights other than those of the United States and those of the State of California.

Estimations of modified natural flows at gaging stations and at other points along the Sacramento River were based upon records of streamflow, diversions, and return flows maintained by the United States Geological Survey and by the Department of Water Resources and its predecessors under the Sacramento-San Joaquin Water Supervision activity. Historical streamflow quantities for months in which no actual records of flow were available were estimated by correlation with flows of the river and/or tributary flows by standard methods. Next, the historical diversions as recorded in the reports of the Sacramento-San Joaquin Water Supervision were added to the recorded or estimated historical streamflows. Then the return flows tributary to the river above each of the points considered were estimated by application of return flow factors to the historical diversions within the appropriate reaches of the river. Finally, such return flows were subtracted from historical flows. Return flow factors were taken as the ratios between average measured accretions to the river, other than accretions from natural streamflows, and the corresponding average monthly diversions within the same month for the period from 1950 through 1984. However, for the dry years of 1924 and 1931 special return flow factors were computed to reflect conditions under deficient water supplies in those seasons.

The second adjustment to measured or estimated historical flows of the Sacramento River at the aforesaid points involved an adjustment for the operation of Shasta Reservoir. This adjustment was made for the years 1943 through 1954. The amounts of increase or decrease in flow were estimated on the basis of the historical monthly changes in Shasta Reservoir storage as corrected for evaporation and precipitation. These data were obtained from the monthly reports of operation for Shasta Reservoir as published by the United States Bureau of Reclamation.

The final adjustment to measured or estimated historical flows of the Sacramento River was to reflect the effect of the 1954 level of diversions in the Feather and Yuba River service areas and in the Butte Creek, Butte Slough and Sutter By-Pass areas. Flows that historically entered the Sacramento River through the Butte Slough outflow gates, in Sacramento Slough and in the Feather River at Nicolaus were adjusted for the differences between historical and 1954 net diversions, to the extent that historical flows were available to meet such differences. Net diversions were taken as the differences between gross diversions and estimated return flows therefrom. Return flow estimates were based upon return flow factors which were computed by a method similar to that described for the Sacramento River.

Modified natural flows of the American River and other tributaries to the Delta were taken as historical flows of those tributaries. Changes in utilization of waters of those tributaries during the study period from 1924 through 1954 has affected water supplies available to the Delta to some extent. However,

the amounts are relatively small, and are believed to be negligible for purposes of the present studies as compared to magnitudes of modified natural flows of the Sacramento River and to possible errors in estimation of such natural flows.

Tables in Volume II indicate estimated quantities of modified natural flows of the Sacramento River at Shasta Dam, at a point above the mouth of Colusa Basin Drain, and at a point above the mouth of the American River, as well as historical flows of the American River at Sacramento and of other Delta tributaries. This information covers the months of April through October from 1924 through 1954. These quantities indicate amounts of water that were initially available to meet assumed diversion rights.

III - ASSUMED WATER RIGHTS

For purposes of the studies described hereinafter, it was necessary to make assumptions as to the water rights of diverters along the Sacramento River and in the Delta. These assumptions pertained to the extent of so-called physically riparian lands, to the extent of appropriative water rights initiated both before and after the Water Commission Act of 1914, and to the extent of lands with a historical water use but not physically riparian and having no apparent claim of water right by virtue of a formal filing with the State. In addition, salinity control requirements and water right status thereof were assumed. It is recognized that the assumed rights may differ from rights that would be determined by the courts through legal processes. For this reason, it is to be emphasized that no claim is made by the parties to the 1956 Cooperative Study Program that these assumptions define the relative water rights involved. Nevertheless, it is believed essential that estimates of these rights be made in order that approximations may be developed of the extent to which such rights may be satisfied from the modified natural flows available.

Information in this chapter is discussed under the headings "Physically Riparian Lands," "Appropriative Water Rights," "Overlap between Physically Riparian Lands and Places of Use under Appropriative Rights," "Other Water Rights," and "Salinity Control."

Physically Riparian Lands

Decisions of the courts in California, including those confirming the 1928 constitutional amendment, have consistently upheld the right of owners of riparian land to divert from the adjacent streams those quantities of water reasonably required on such lands. Along the Sacramento River these riparian rights under State law are believed to be prior to any rights acquired by reason of appropriation.

Estimates of the extent of physically riparian land along the Sacramento River between Redding and Sacramento were based upon extensive work by the Bureau of Reclamation which began about 1950. This work consisted of contracting with title companies for title reports on each parcel of land believed to be physically riparian to the Sacramento River. These reports indicated the smallest parcels of land abutting the river that have been in continuous ownership since the date of patent, thereby meeting the requirements for riparian status. Upon receipt of the title reports, the Bureau of Reclamation delineated the boundaries of such smallest contiguous parcels on maps, using aerial photographs to assist in plotting. The boundaries of the physically riparian parcels were then projected upon maps showing the extent of irrigation systems in existence at the time of study and showing the lands within the boundaries that were considered to be irrigable.

The foregoing work by the Bureau of Reclamation was spot-checked under the 1956 Cooperative Study Program to confirm the validity of the methods used and the accuracy of the computations. This examination indicated that the basic studies had been carefully performed, and they were taken as acceptable for use in the

cooperative studies. Plate 2, entitled "Assumed Physically Riparian Lands and Boundaries of Major Entities North of Sacramento", indicates the backline of physically riparian lands along the Sacramento River between Redding and Sacramento, as determined by the method described heretofore.

The aforesaid determination indicated that there are approximately 169,000 acres of physically riparian land along the Sacramento River between Redding and Sacramento, of which approximately 110,000 acres are either under existing water distribution systems or are irrigable areas not now served with water. Water requirements of these lands were estimated by assuming that 85 per cent of the irrigable area will be irrigated in any one year with a unit duty of one second-foot per 70 acres. This is equivalent to a diversion demand of approximately 82,000 acre-feet or 1,335 second-feet in the month of maximum demand.

It was assumed that all of the Delta Lowlands are riparian to channels of the Delta. The boundaries of this area are shown on Plate 3, entitled "Boundaries of Major Entities in and Subdivisions of Sacramento-San Joaquin Delta". Furthermore, in certain studies described hereinafter, it was assumed that such lands are riparian with respect to waters of the Sacramento River and to other tributary streams of the Delta. No search of individual title records, such as that described for the Sacramento River north of Sacramento, were made for this Delta Lowlands area. The boundary of the Delta Lowlands is the same as that shown on Plate 3 in the report entitled "Sacramento River and Sacramento-San Joaquin Delta Trial Water Distribution 1955 Summary Report of Data," dated January 1956. The gross area of the Delta Lowlands

is approximately 469,000 acres, of which 386,000 acres were classified as agricultural in a land use survey made by the State. Water requirements for this area were estimated on the basis of the areas of land use given in Table 18 of the aforesaid report and of unit consumptive use of water factors given in Table 20 of that report. Total amounts of consumptive use computed in that manner were reduced to account for the estimated portion of the total consumptive use that may be supplied by precipitation to determine the net demand upon Delta channels. These estimates considered both precipitation during the month in question and that carried over as soil moisture from earlier precipitation. The net consumptive use in the Delta Lowlands in the months of maximum demand was estimated to be 241,000 acre-feet or an average of 3,919 second-feet.

In the determination of physically riparian lands along the Sacramento River above Sacramento and in the Delta Lowlands, no study was made of the possible modification of the rights of such lands by reason of adverse use developing into a prescriptive right. It is believed that such studies would be in the nature of judicial determinations and are, therefore, beyond the scope of an engineering study of the type described in this report.

Table 1 of Appendix D summarizes the water requirements of assumed physically riparian lands north of Sacramento and in the Delta Lowlands. It includes estimates of water requirements of riparian land within the service areas of major entities above Sacramento, the boundaries of which are among those delineated on Plate 2.

Appropriative Water Rights

Appropriative water rights considered in the 1956 Cooperative Study Program include those initiated by posting and those initiated by filing pursuant to the Water Commission Act of 1914.

Information on appropriations initiated prior to December 19, 1914, the effective date of the Water Commission Act, were taken from various sources including the factual reports by the Bureau of Reclamation, covering the Sacramento River Service Area Investigations, and Bulletin No. 21 of the State Division of Water Resources entitled, "Report on Irrigation Districts in California" published in 1929. The right of Anderson-Cottonwood Irrigation District was assumed to be 400 second-feet as indicated in a certificate issued by the Water Commission which confirmed their 1914 posting. The amount of the appropriative right for Glenn-Colusa and Jacinto Irrigation Districts was assumed to be 2,400 second-feet or the capacity of the main canal.

In studies of the rights of individual water users described in the next chapter, pre-1914 posting information was also obtained for several of the major diverters in the Delta Uplands. The assumed amounts of vested rights under these postings were taken as the maximum historical monthly average diversions thereunder.

Appropriations initiated under the Water Commission Act of 1914 were evaluated from the information given in the application, permit, or license on file with the State Water Rights

Board. The assumed amounts of such rights were taken as the face values given in those documents without modification for change of development or for loss of right by reason of non-use. Applications for water rights were considered and tabulated if the date of application was December 31, 1954, or earlier. The values of State Department of Finance filings made in 1927 and subsequently, including those assigned to the United States, were also taken from the files of the State Water Rights Board.

Appropriative rights in the Delta Uplands were not studied in detail for the first two series of studies described in the following chapter. By inspection of records of diversions in the Delta Uplands in 1955, it was found that approximately 70 percent of such diversions were made under appropriations antedating the State filings of 1927. It was also found that the remaining portion, or approximately 30 percent of the 1955 diversions, were made under water right applications subsequent to 1938, the date of the second group of State filings assigned to the United States for the Central Valley Project. In later studies of individual water users in the Delta Uplands, application, permit, and license data were taken as the bases for appropriative water rights initiated subsequent to 1914.

Table 2 of Appendix D presents assumed values of vested appropriative rights under postings and Table 3 of that appendix presents a chronological tabulation of the assumed appropriative water rights initiated between 1914 and 1954. Those tables show the names of only those major appropriators assumed to have pre-1927 water rights which were studied

individually as described in the next chapter. The present holders of other applications, permits, or licenses were not determined. The boundaries of the properties and districts to which the maps of pre-1927 appropriative water rights pertain are among those indicated on Plate 2. Table 5 of Appendix D presents information on the various State filings considered in this report.

Overlap Between Physically Riparian Lands and Places of Use Under Appropriative Rights

As indicated on Plate 2, the boundaries of certain of the entities that have claimed appropriative water rights overlap the physically riparian lands also shown on that plate. Therefore it was necessary to eliminate the duplication of coverage by appropriative water right service areas and physically riparian lands.

The Bureau of Reclamation had made a study of the extent of the overlap between lands covered by these two different categories of water rights. This study involved plotting the respective areas on a set of maps similar to the maps shown as Plate 2 of this report, but at a larger scale. The determinations of the extent of overlap were checked in the 1956 Cooperative Study Program to determine the reasonableness of the method of derivation and the accuracy of that work.

Water requirements for the overlap areas were estimated by assuming that such areas would retain the same duties of water as specified in the applications, permits, or licenses covering the areas. The overlap allowance was then deducted from the total allowance for the area covered by the appropriation.

Table 3 of Appendix D also presents the estimated requirements for overlap areas, and the net assumed appropriative water right entitlements after correction for overlap. These assumed net

rights total 412,000 acre-feet or an average of 6,700 second-feet during the month of maximum demand.

Other Water Rights

It has been mentioned heretofore that records of water use on lands along the Sacramento River between Redding and Sacramento indicate that there are parcels of land which are not covered by assumed riparian or appropriative rights but which, nevertheless, have been irrigated from the river over long periods of time and were irrigated in 1954. Whatever the basis or claim of right may be for these lands, it was assumed in the 1956 Cooperative Study Program that such lands do have a right to divert water. Further, it was assumed that such rights have a priority in accordance with the approximate date on which the use of water was initiated as shown by the historical records. The work of determining such "other" rights was originally done by the Bureau of Reclamation and was checked in the cooperative studies.

Table 4 of Appendix D indicates the quantities of assumed "other" water rights along the Sacramento River between Redding and Sacramento. These assumed rights total 16,780 acre-feet or an average of 273 second-feet during the month of maximum demand.

Salinity Control

It has been indicated heretofore that use of water within the Delta Uplands and Lowlands and diversion of water from the Delta through facilities of the Central Valley Project and diversion works of the City of Vallejo require salinity control in order to prevent harmful degradation of the quality of water in Delta channels. Under natural conditions such salinity control

was probably provided in most years by surplus outflow of fresh water from the large tidal swamp which then comprised the area at the confluence of the Sacramento and San Joaquin Rivers, which we now call the Delta. Gradually, as reclamation of the Delta and development of the use of water took place upstream, the amount of water available for natural salinity control decreased until in 1924, 1931, and other dry years, the encroachment of saline waters reached serious proportions. During the late summers of those years irrigation in a large part of the Delta was made impossible by the degree of concentration of salinity in the waters of the channels.

One of the functions of the Central Valley Project is to regulate surplus runoff from the Sacramento and American Rivers so as to provide sufficient outflow from the Delta to repel salinity. Since actual operation of Shasta Reservoir commenced in 1944, incursion of sea water to the extent that took place in the former years of uncontrolled runoff has been largely prevented. However, in some recent years concentrations of chlorides have exceeded 1,000 parts per million in the channels adjoining some of the westernmost Delta islands and have, therefore, exceeded the standard that was adopted by the State as a minimum for use of the water for agricultural and other purposes.

Bulletin No. 27 of the State Division of Water Resources entitled "Variation and Control of Salinity in Sacramento-San Joaquin Delta and Upper San Francisco Bay" and published in 1931, presented an analysis of the historical records of saline water incursion and recommended that salinity control outflows from the Delta be maintained at a minimum constant flow value of 3,300 second-feet. It

was estimated in that bulletin that such outflows would prevent excursion of chloride ion concentrations of 1,000 parts per million beyond points in the San Joaquin and Sacramento Rivers approximately six-tenths of a mile west of Antioch.

In certain of the studies described in this report, the assumption was made that salinity control flows of 3,300 second-feet had, in effect, a status as a riparian water right associated with the assumed riparian rights of the Delta Lowlands since such salinity control outflows would be required to make such riparian diversions possible. However, there is some question as to the economic value of providing a full 3,300 second-feet outflow for salinity control, which would be required to protect diverters in the westernmost part of the Delta. It has been suggested by some investigators that the amount of water allowed to waste to Suisun Bay for control of salinity should be reduced below the amount of 3,300 second-feet and that direct overland service of fresh water be provided to those westernmost areas that would be unable to divert directly from the channels with such lesser amounts of salinity control. Therefore, certain of the studies described in this report were based upon the assumption that salinity control flows having a riparian water right status would be 2,000 second-feet instead of 3,300 second-feet. In addition one of the cooperative studies was based upon the assumption that salinity control requirements of 3,300 second-feet would have a water right priority subsequent to 1954, following the priority dates of all appropriative rights assumed for the studies. This assumption was made for illustrative purposes only.

IV - YIELDS OF ASSUMED WATER RIGHTS

On the basis of estimated modified natural flows and assumed water rights described in the preceding chapters, estimates were made of the yields of assumed water rights under several combinations of assumptions. Three different general groups of studies were made in this connection. The so-called "A" and "B" Series of studies considered large groups of local water right claimants separated by the priority dates in 1927 and 1938 pertaining to the State filings which were assigned to the United States for construction of the Central Valley Project. In these series, the yields of assumed local rights and of the 1927 and 1938 filings assigned to the United States were estimated. In addition, one study under each series produced estimates of yields of those State filings still retained under the jurisdiction of the State Department of Water Resources. The "C" Series of studies considered the yields of individual major appropriative water right claims of 25 major entities along the Sacramento River above Sacramento and in the Delta Uplands, as well as the yield of assumed riparian rights of the Delta Lowlands and of other water users as a group. As indicated heretofore, assumptions as to the amounts and water right status of requirements for salinity control were made for the various studies.

The general procedure for making these studies involved deducting gross diversions from amounts of modified natural flows available in various reaches and crediting amounts of return

flows from such diversions to permit additional use of water. Further details with respect to each of the studies is presented in the following sections pertaining specifically to each of the study series.

"A" Series

For purposes of the "A" Series of studies, assumed water rights were divided into five groups in order of priority as follows: (1) riparian and pre-1927 appropriative and other rights of local water users, (2) 1927 State filings, (3) appropriative and other rights of local water users with priority between 1927 and 1938, (4) 1938 State filings, and (5) post-1938 appropriative and other rights of local water users. These water rights were further subdivided geographically into two reaches above Sacramento, namely, Redding to Knights Landing and Knights Landing to Sacramento. The pre-1927 rights assumed for the Delta Lowlands and Delta Uplands were taken as one geographical group.

The general procedure for determining yields which was followed in each study of the "A" Series involved the assumption that local water rights within each priority group would be satisfied in geographical order proceeding downstream from Redding. Modified natural flows in the reach Redding to Knights Landing were assumed to be available first for satisfaction of all rights of the first priority group within that reach. Return flows from diversions under such rights were estimated by using return flow factors previously described in the chapter on modified natural flows. Such return flows were assumed to be available for one level of rediversion if needed to meet the rights of the first

priority group. Return flows from such rediversions were assumed to be unavailable for further diversions in the reach. It was believed that such return flows would occur in a manner that would make a second rediversion in the same reach impracticable. The sum of any modified natural flows remaining after the aforesaid diversions and return flows from upstream diversions was assumed to be available to satisfy water rights of the first priority group in the second reach between Knights Landing and Sacramento. The extent of satisfaction of the assumed water rights for the second reach was then determined in the same manner as in the first reach. Finally, the assumed water rights of the first priority group in the Delta, including the requirements for salinity control at 3,300 second-feet, were assumed to be satisfied to the extent possible from any residual modified natural flows and from return flows from diversions in the upper reaches.

Yields of assumed water rights in the second priority group, the 1927 State filings, were estimated next. They were taken as being satisfied to the extent possible from any water available after satisfaction of all assumed water rights in the first priority group. At this point, the differences between the three studies of the "A" series are to be found in part. For Study A-1, only the 1927 State filings on the Sacramento River at Shasta Dam, which were assigned to the United States, were considered. For that study, the portion of the demand under those filings for diversion into the Delta-Mendota Canal was assumed to comprise a constant diversion rate in all months studied, amounting to 4,600 second-feet.

Study A-2 was the same as Study A-1, except that the diversions from the Delta into the Delta-Mendota Canal under 1927 State filings were assumed to follow an irrigation demand schedule with a peak in July and with lesser amounts in other months instead of the constant rate of demand assumed for Study A-1. Study A-2 (Modified) differed from the other two studies of the "A" Series in that assumed amounts of 1927 State filings on the Feather, Yuba, Bear, American, Middle Fork of the Stanislaus, and San Joaquin Rivers, in addition to State filings of 1927 priority at Shasta Dam assigned to the United States, were assumed to be a demand upon waters remaining in those streams after satisfaction of assumed pre-1927 rights of local water users. This had the effect of reducing quantities of water available to the Bureau of Reclamation.

In all of the studies described pertaining to computation of the yields of water rights of the second or 1927 priority group, it was assumed that direct diversion rights would be satisfied first and that storage rights would be satisfied second. In Study A-2 (Modified) assumed State filings on the Stanislaus and San Joaquin Rivers were taken as being satisfied before any other 1927 rights. To the extent that flows were available at or near points referred to in those filings, historical flows of the San Joaquin River at Vernalis were reduced to meet the filing quantities. The portions of such reductions that in turn would increase deficiencies in yields of pre-1927 Delta rights were made up from surplus waters of the Sacramento River and its tributaries in the Sacramento Valley. Remaining waters available for State filings on the Sacramento, Feather, Yuba, Bear, and American Rivers were assumed to be used

to satisfy those filings in proportion to historical flows at the points referred to in the filings. 1934 State filings on the American River were considered along with 1927 filings because there were no assumed local rights having priorities between those years.

Yields of assumed appropriative and other water rights of local water users in the third group, having priorities between 1927 and 1938, were estimated next. They were taken as being satisfied insofar as possible from water still available after satisfaction of the pre-1927 water rights of local water users and 1927 State filings. The procedure was the same as that followed in determining yields of assumed pre-1927 water rights, in which assumed rights were satisfied in geographical order beginning with the highest reach on the river, proceeding downstream, and utilizing return flows.

Following this, yields of assumed water rights in the fourth priority group, the 1938 State filings were determined. The 1938 State filings in the Delta were considerably larger than the capacities of diversion works of the Central Valley Project. Consequently those filings were assumed to be utilized only to the extent necessary to complete the satisfaction of demands for the Delta-Mendota and Contra Costa Canals not met under the assumed 1927-priority rights at Shasta Dam.

As in the case of the assumed 1927-priority State filings, there are differences in assumptions as to amounts of the 1938 filings as among the three studies of the "A" Series. In Study A-2, amounts of water required to make up the differences between

Delta-Mendota Canal diversions under an irrigation demand of 4,600 second-feet were assumed to be constant throughout the study period. Divisions at a constant rate of 4,600 second-feet were assumed to be constant throughout the study period. This caused yields of assumed rights of the United States to be larger under Study A-2 than under Study A-1. In addition, under the 1938 State filings assigned to the United States, it was assumed for Studies A-2 and A-2 (Modified) that the demand for municipal and industrial purposes would be 1,000 second-feet instead of the figure of 100 second-feet assumed for Study A-1. The basis for the 1,000 second-foot value is Application No. 9363 listed in Table 5 of Appendix D.

The final step of the "A" Series studies was to determine the yields of the fifth group, assumed local rights having post-1938 priorities. These local water rights were assumed to be satisfied by waters remaining after satisfaction of 1938 State filings in geographical order starting with the highest reach on the river, proceeding downstream, and utilizing return flows.

Tables 1 through 12 present average monthly values of yields of assumed rights of local water users and of the Bureau of Reclamation under the "A" Series for the years 1924 through 1954. Those tables also show assumed water rights for the respective studies to permit ready comparison with corresponding values of average yield. Included in Volume II are tables showing the estimated yields of the various water right priority groups for each month of the 31-year period from 1924 through 1954. Plate 4, entitled "Assumed Water Rights, Yields, and Supplemental Water Requirements 1924-1954 Under Study A-2" includes a graphical representation of the yields of the assumed rights of all local water users, those of the Bureau of Reclamation, and that for salinity control.

"B" Series

The computation procedures to estimate water rights under the "B" Series were similar to those described for the "A" Series with one principal exception. In the "B" Series all of the assumed riparian rights, both above Sacramento and in the Delta Lowlands, and the salinity control requirement, when it was assumed to have a riparian water right status, were taken as being satisfied before any appropriative water rights. After such riparian rights were satisfied to the extent of available water supplies, the remaining flows at points along the Sacramento River and in the Delta were assumed to be available to satisfy appropriative water rights. Yields of assumed appropriative rights of local water users within each priority group were estimated by assuming that rights in the uppermost reach of the river between Redding and Knights Landing would be satisfied first, followed in succession by rights in the reach between Knights Landing and Sacramento and by rights in the Delta Uplands. Return flows from diversions within each reach were treated in the same manner as that described for the "A" Series of studies in order to compute the total amount of water available for diversion in each reach.

For Studies B-1, B-2, and B-2 (Modified), the water right assumptions and computation procedures pertaining to rights under State filings assigned to the United States and State filings remaining unassigned were the same as assumptions for the three studies of the "A" Series, respectively. Water right assumptions for Study B-3 followed assumptions for Study B-2 with the exception that salinity control outflows from the Delta assumed to have a riparian

water right status were taken at 2,000 second-feet instead of 3,300 second-feet. Assumptions for Study B-4 were the same as those for Study B-2 except that a salinity control requirement of 3,300 second-feet was assumed to have a water right priority subsequent to 1954 following all appropriative rights considered in the studies. As indicated heretofore, this assumption was made for illustrative purposes only.

Average monthly values of water-right yields for the period 1924 through 1954 for the studies of the "B" Series are also summarized in Tables 1 through 12 of this report. Included in Volume II are tables showing the yields of the various water right groups for each month of the 31-year period 1924 through 1954. Plates 5, 6, and 7, under the general title "Assumed Water Rights, Yields, and Supplemental Water Requirements 1924-1954", show graphically the yields of the various water rights groups under Studies B-2, B-3, and B-4, respectively.

Comparison of Average Yields of Water Rights Under "A" and "B" Series

The studies of the "A" and "B" Series demonstrate the range of yields that result from those variations of water right assumptions used in the studies. As indicated heretofore, comparisons of the yields are presented in Tables 1 through 12. Such comparisons are also shown graphically on Plate 8, entitled "31-Year Average Yields of Assumed Rights of Bureau of Reclamation and Local Water Users". Plate 9, entitled "31-Year Average Difference or Deficiencies Between the Yields of All Assumed Rights and the 1954 Level of Diversions and Supplemental Water Requirements by Local Water Users", presents diagrammatically a comparison of information

pertaining to assumed water rights and yields thereof for the Delta Lowlands of the "A" and "B" Series.

A number of conclusions may be drawn from the results of the various studies of the "A" and "B" Series presented in the aforesaid tables and plates. Some of the more important conclusions are as follows:

1. The total-irrigation-season yields of the assumed Delta Lowlands rights are greater in the "B" Series than in the "A" Series because in the "B" Series those rights are generally satisfied before any appropriative water rights. Conversely, yields of assumed rights along the Sacramento River above Sacramento are greater in the "A" Series than in the "B" Series.
2. The yields of all assumed local water rights under the first three studies of the "A" Series do not differ greatly because of the large percentage of such local water rights assumed to have a pre-1927 water right status and because variations in assumptions affected only water rights of 1927 and later priorities. The same is true of the first three studies of the "B" Series.
3. The yields of assumed 1927-38 and post-1938 rights of local water users are small in the months of July through October.
4. The total yields of assumed rights of the United States under Studies A-2 and B-2 are greater than

yields under Studies A-1 and B-1, respectively, because greater water demands for municipal and industrial purposes under the 1938 State filings were assumed in Studies A-2 and B-2.

5. The total yields of assumed water rights of the United States are lower under Studies A-2 (Modified) and B-2 (Modified) than under A-2 and B-2, respectively, because portions of the available water supplies after satisfaction of the assumed pre-1927 rights are required to supply the assumed values of unassigned State filings.
6. The total yields of assumed rights for both local water users and the United States are greater in Study B-3 than in Study B-2, both of which are based largely on the same water right assumptions, because in Study B-3 salinity control requirements having a riparian status were assumed to be 2,000 second-feet instead of 3,300 second-feet, thereby increasing amounts of water available for appropriators.
7. Similarly, the total yields of assumed rights of local water users and of the United States are greater in Study B-4 than in the Study B-3 because of the assumption for Study B-4 that all salinity control requirements have a late priority status.

"C" Series

As previously discussed, the "A" and "B" Series considered only broad priority groups which were separated by the dates in 1927 and 1938 when State filings were made which were later assigned in part to the United States. An essential objective of the 1956 Cooperative Study Program is the derivation of methods of allocation of responsibility for purchase of supplemental water among the individual water users so that each might pay for the water required to firm up the estimated yield of his right. Studies of the "C" Series were designed specifically to provide parameter values for use in allocating responsibility for supplemental water.

The "C" Series produced estimates of the yields of assumed water rights of the Delta Lowlands and of assumed riparian and appropriative water rights of 26 major water diverters along the Sacramento River above Sacramento and in the Delta Uplands. The 26 water diverters were selected on the basis of their having large assumed riparian or appropriative water rights of pre-1927 priority. One of these entities was assumed to base its water right claim entirely upon its riparian status and the remaining 25 were assumed to base their claims upon appropriation alone or upon appropriation plus possession of riparian land. Studies of the "C" Series also determined the collective yields of water rights of other water users not considered individually.

Two "C" Series studies were made. Study C-1 was based upon the first phase of Study B-1 up to the point of determining the yield of assumed riparian rights, and Study C-2 was similarly

based upon the first phase of Study B-4. Each of these "B" Series studies then involved estimation of the yields of the assumed appropriative rights of each of the 25 major water diverters in order of priority regardless of location along the Sacramento River or in the Delta Uplands.

The method involved first the tabulation of net requirements of assumed appropriative water rights with consideration being given to the appropriate return flow factor for the reach to which the appropriation applied. All assumed net appropriative rights were then arranged in order of decreasing priority. The extent to which water remaining at various points along the river and in the Delta after satisfaction of riparian rights could satisfy assumed appropriative rights was determined for each month by reference to this tabulation. If there was water available in a given month after satisfaction of all pre-1927 appropriative rights, the remainder was assumed to be available to satisfy the assumed rights of the United States under the water right assumptions of the corresponding "B" Series studies. Similarly if water remained after satisfaction of 1927 State filings assigned to the United States, the remainder was distributed among local rights of 1927 to 1938 priority, 1938 State filings, or post-1938 local water rights, depending upon the amount of water available.

Tables 13 and 14 indicate the estimated average monthly water-right yields during the study period 1924 through 1954 for each of the 26 major water users and for the Delta Lowlands. The tabulations indicate the yields of assumed riparian rights of each of the 26 major water users as well as yields of their appropriative rights.

Comparison of Tables 13 and 14 indicates that groundwater yields for the local water users result from the assumption that salinity control requirements have a late priority status, as in Study C-2, than if such requirements are assumed to have a riparian water right status, as in Study C-1.

V - DEFICIENCIES AND SUPPLEMENTAL WATER REQUIREMENTS

In order to evaluate the amount of water required by local water users along the Sacramento River and in the Delta from storage facilities of the Central Valley Project, from other storage facilities, or from importation it is desirable to determine the deficiencies in yields of assumed water rights from available flows and amounts of supplemental water required in order to permit a given level of diversions. "Deficiencies" are defined for purposes of this report as the differences between the individual or collective yields of assumed local water rights and the face values of such rights or a given level of water utilization. For most studies, the 1954 level of diversion along the Sacramento River, and the 1955 level of water utilization in the Sacramento-San Joaquin Delta for purposes other than salinity control were selected for determination of deficiencies. Those levels of water utilization were chosen because they are the maximum historical levels. In negotiation of an agreement the water users may wish to choose a different level of diversions from the 1954 and 1955 levels. The effects of such different diversion levels may be estimated on the basis of values given in this report.

The term "supplemental water requirement" is defined for purposes of this report as the actual release of water required from reservoirs of the Central Valley Project or from any other reservoirs or sources in order to overcome the aforesaid deficiencies. Supplemental water requirements are less than corresponding

deficiencies by the amount of return flow available for redemption. Estimates of supplemental water requirements also pertain to the 1954 level of diversions along the Sacramento River and to the 1955 level of water utilization in the Delta.

Deficiencies

Deficiencies for the "A" and "B" Series were taken as the differences between the yields of assumed water rights and the 1954 level of diversion along the Sacramento River or the 1955 level of water utilization in the Delta. Values of those levels of diversion and water utilization are given in Table 6 of Appendix D. The aforesaid differences were determined for each of the three priority groups of local water rights as divided by the years 1927 and 1938. Total deficiencies were computed by adding together the deficiencies for all of the priority groups.

Deficiencies were also estimated for the various subdivisions of water rights considered in the "C" Series. These deficiencies were not based upon the 1954 or other recent level of diversions but were assumed to be the differences between the yields of the individual or collective water rights considered and the full face value of those respective rights. This assumption was necessary because the pattern of individual diversions varies considerably from year to year making application of the 1954 level of diversions by each water diverter unrealistic over a long period of years. Therefore deficiencies determined for the "C" Series were used only for the purpose of computing possible parameters for allocation of requirements for supplemental water as determined for the "A" and "B" Series.

on. Tables 15 through 19 present estimates of average deficiencies in yield of assumed local water rights as determined by the "A" and "B" Series. Tables 20 and 21 present the estimated deficiencies for the "C" Series.

he Comparison of the average deficiencies in yields of local water users, as shown by the results of the various studies of the "A" and "B" Series, reveals that as the assumptions vary so as to increase the yields of the local water rights the deficiencies decrease and vice versa. Similarly in the "C" Series, the individual water rights are satisfied to a greater extent and the deficiencies are less in the C-2 Study than in the C-1 Study because the C-2 Study is based upon the assumption that all salinity control requirements have a late priority status.

Supplemental Water Requirements

Supplemental water requirements were estimated for both the "A" and "B" Series on the basis of the deficiencies described in the preceding section. Such requirements were estimated by reducing the deficiencies to allow for reuse of return flows. Return flows were based upon application of return flow factors previously discussed.

Tables 22 through 26 indicate the estimated supplemental water requirements under the "A" and "B" Series. These are average monthly values for the period of study from 1924 through 1954 based upon the 1954 level of diversion along the Sacramento River and the 1955 level of water utilization in the Delta.

No supplemental water requirement estimates were made under the "C" Series for reasons previously discussed in connection with deficiencies. Supplemental water requirements for individual water users were estimated from the results of the "A" and "B" Series by application of allocation parameter values based upon results of the "C" Series. These allocation studies are described in the next chapter.

VI - ALLOCATION STUDIES

As indicated heretofore, various water right assumptions were made in this report for study purposes. It has also been indicated that the quantities of such rights as they might be determined by a court of law could differ substantially from the values presented in this report. Some of the reasons for these differences could be consideration of diligence in the development of beneficial use under the various appropriative water right applications, the loss of appropriative rights by non-use, the actual extent of lands having a riparian right upon waters of the Sacramento River both above Sacramento and in the Delta, the effect of prescription upon the various water rights assumed, and the status of water requirements for salinity control with relation to other water rights along the river and in the Delta. These factors suggest the possible wide range in amounts of supplemental water supplies that each water user might be considered to be responsible for in view of the yield of his water rights and the level of diversion which he might wish to maintain.

The foregoing consideration indicated to the cooperative engineering group the desirability of developing formulae for determining (1) the amount of supplemental water that the water users as a group should acquire and (2) the manner in which this obligation should be distributed among the individual water users. Because of the uncertainties as to the specific water rights

involved, it is believed that the only practicable method of accomplishing those objectives is by compromise based upon estimated requirements for supplemental water such as those indicated by studies in this report. The studies described in the preceding sections are believed to present a reasonable range of assumptions with relation to the extent of water rights under State filings and to the water right status of salinity control requirements. As previously indicated no attempt has been made to evaluate the effects of diligence or loss of right by nonuse or prescription. This course was taken because (1) it was believed that such matters are primarily of a legal and judicial nature beyond the scope of an engineering study and (2) the conceivable combination of assumptions related to those matters was so great as to be impracticable within the limitations of time and personnel available for the 1956 Cooperative Study Program.

This section presents some of the possible ways by which the deficiencies in yields of assumed individual and collective rights, as estimated in the "C" Series, might be used to allocate among the diverters the overall obligations of the water users for purchase of supplemental water, as derived by the "A" and "B" Series. Possible means of allocation and examples of such allocations of responsibility for supplemental water requirements for irrigation and municipal purposes are discussed separately from possible allocations of the responsibility for salinity control.

Allocation of Responsibility for Supplemental Water Requirements
for Irrigation and Municipal Purposes

The following discussion pertains to the average allocation of responsibility for supplemental irrigation and municipal water requirements based upon the historical water supply conditions that prevailed during the months of April through October in the years 1924 through 1954. These quantities give an indication of the average allocation that might apply over a long period of years under conditions of water utilization approximating those in 1954 and 1955.

The allocation procedure involved multiplying the total indicated requirements for supplemental water for all local water users by parameter values comprising ratios between the individual deficiencies and the total deficiency of all water users under the "C" Series. Parameter values are shown in Appendix E. Supplemental water requirements for all local water users as determined in Studies A-2, B-2, B-3, and B-4 were utilized together with the results of studies C-1 and C-2 to derive examples of possible allocations. Other similar allocations might also have been made by application of parameter values given in Appendix E to total seasonal values of supplemental water requirements for Studies A-1, B-1, A-2 (Modified), and B-2 (Modified), as given in Table 24, or to any other values.

Presented in Table 27, is a summary of allocation results which were obtained by applying the allocation parameters, based upon Studies C-1 and C-2, to the total supplemental irrigation and municipal water requirements as determined by the various studies of the "A" and "B" Series. In addition, unallocated total

supplemental water requirements for salinity control are shown for each study.

The aforesaid examples indicate relatively small differences in allocations for most major water users as between the results of applying the C-1 and C-2 parameters. This is true despite the significant differences between Studies C-1 and C-2 with regard to assumptions of the water right status of salinity control. The principal exceptions to the aforesaid rule are in the cases of the Glenn-Colusa Irrigation District and of "Other Water Users".

Allocation of Responsibility for Salinity Control

All of the uncertainties as to legal bases for final allocation of available natural flow described in the first paragraph of this chapter are applicable to salinity control. However, it may be said in general that the Delta water users and the Central Valley Project now receive, and that the State's Feather River Project will receive direct benefits from salinity control. It may also be said that upstream water users along the Sacramento River and other tributaries of the Delta receive certain indirect benefits from such control. Thus an interrelationship exists among the aforesaid benefits.

There may be differences of opinion both as to the relative responsibilities for salinity control among the governmental agencies concerned and among groups of water users and as to the degree of control that should be provided. There may also be various opinions regarding alternative economical and reasonable methods of providing water of good quality for diversion

from the Delta. No attempt is made to in this report to address these matters, because it appears that such determinations are beyond the scope of an engineering study and are in the realm of arbitrary compromise. Therefore no specific method of allocation of responsibility for flood control is suggested in this report.

Allocation Under Operating Conditions

It has been indicated that the methods of allocation of responsibility for supplemental water requirements, suggested in this report, pertain to average conditions under water supplies prevailing in the years from 1924 through 1954. It has also been stated that this procedure permits the water users to view the average results of the various assumptions as to allocation methods that might apply over such a period.

This does not preclude use of this type of allocation procedure under operating conditions, if it is decided to base the annual payment for supplemental water upon anticipated water supply conditions and conditions of demand occurring during each specific year. On the basis of these conditions, estimation of the total responsibility of all local water users could be accomplished without difficulty at the beginning of each irrigation season. A number of possible alternatives are available for allocation of this overall responsibility. One would involve multiplying the total requirement for supplemental water for all local water users by average allocation parameter values, such as those mentioned previously, to determine the obligation of each water user during the year in question. This might be considered

reasonable if each water user were willing to concede that for a period of years his water diversions with relation to diversions by other water users would average about the same as the diversions upon which the parameter values were based.

A second method of allocation under actual operating conditions might be based upon parameters computed specifically for each season. Such parameters would depend upon each water user's contemplated diversions and the probable yield of his water rights for the season in question as compared to such data for all local water users. It is believed practicable to devise a formula whereby parameters, such as those described in this chapter, might be modified in an approximate manner to accomplish this end.

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VII - SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This chapter presents a brief summary of the assumptions and procedures in studies under the 1956 Cooperative Study Program and the more significant conclusions resulting therefrom. Recommendations for future action on matters with which this report is concerned, are presented.

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Summary

The 1956 Cooperative Study Program was commenced in May, 1956, cooperatively by the United States Bureau of Reclamation, the State Department of Water Resources, and the Sacramento River and Delta Water Association. The purpose of these studies was to indicate the effects upon the United States and upon local water users of different assumptions as to water rights, particularly as to rights along the Sacramento River and in the Sacramento-San Joaquin Delta, with respect to the adequacy of unregulated stream flow to meet the current needs of the water users for irrigation and for salinity control in the Delta and conversely the need for supplemental water from the Central Valley Project under these varying assumptions. It was intended for these studies to produce information that would be used to further negotiations aimed at reaching agreement on water rights along the Sacramento River and in the Delta.

A total of ten complex studies was made to evaluate, under different assumptions as to water rights, yields of water rights and the monthly quantities of water available for satisfaction of such

rights from flows of the Sacramento River and from Delta channels without regulation by reservoirs of the Central Valley Project in the Sacramento Valley. The 31-year period 1924 through 1954 was used for study purposes because essential hydrographic records were available in sufficient detail for that period. The years 1955 and 1956 were not included because a number of final hydrographic records were not available. Only the months of the irrigation season from April through October of each of those 31-years were studied because it was found that unregulated water supplies in all other months were generally ample for all requirements. Average values for the irrigation seasons in those years are referred to in this chapter as "31-year-average-irrigation-season" values. Monthly deficiencies were also estimated for each study as the differences between water right yields and the 1954-55 diversion level or, in several cases, the values of assumed rights. Monthly quantities of supplemental water required to firm the water right yields to the 1954-55 diversion level were also estimated. Finally, quantities of water remaining at the various points along the River after satisfaction of various water rights were computed. These results are shown in Volume II of this report but are not discussed in Volume I.

The water right assumptions, which were made for this report, were solely for the purpose of evaluating the effects of these assumptions upon water right yields, deficiencies, and supplemental water requirements, and no implications as to the legal status of such assumed rights are intended. Assumed quantitative values, or "face" values, of water rights were based upon

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estimated water requirements for areas of physically riparian land along the Sacramento River above Sacramento as derived from title search records; upon records of historical use of water under appropriations by postings made prior to 1914, as shown in county records; upon records of appropriation made subsequent to 1914, as shown in the files of the State Water Rights Board; and upon records of water use over a substantial period of years on lands not assumed to be physically riparian and having no apparent claim of appropriative water right referred to hereinafter as "other" water rights. It was assumed that all Delta Lowlands as shown on Plate 3 are riparian to the channels of the Delta and to waters of tributary streams. Navigation requirements along the Sacramento River were ignored. For purposes of studies of the "A" and "B" Series, described hereinafter, the assumed water rights were assembled into five priority groups as follows:

Priority Group 1 - Assumed local rights of pre-1927 (July 30, 1927) priority including water requirements of assumed physically riparian lands along the Sacramento River north of Sacramento and in the Delta Lowlands, pre-1914 appropriations by posting, 1914-1927 appropriations under the Water Commission Act of 1914 and assumed pre-1927 "other" water rights. In some studies, salinity control requirements of 3,300 or 2,000 second-feet were assumed to be analogous to riparian rights and were considered in this priority group.

Priority Group 2 - Assumed rights under State Department of Finance applications filed July 30, 1927, including those at Shasta Dam assigned to the United States for the Central Valley Project and in some studies other State filings on the Feather, Yuba, Bear, American, Stanislaus, and San Joaquin Rivers.

Priority Group 3 - Assumed local appropriative and "other" rights of priority between July 30, 1927 and August 2, 1938.

Priority Group 4 - Assumed rights under State Department of Finance applications filed on August 2, 1938, and assigned to the United States for the Central Valley Project.

Priority Group 5 - Assumed local appropriative and "other" rights of priority between August 2, 1938 and December 31, 1954, and in some studies assumed rights under State filings on the Feather River in 1951. In two studies a salinity control requirement of 3,300 second-feet was assumed to have a status analogous to an appropriative water right of post-1954 priority.

Several of the assumptions were the same for each study but other assumptions were varied among the studies. In all studies, the face value of 1927 State Application No. 5626 at Shasta Dam, assigned to the United States, was assumed in full but with variation in the monthly distribution of demand as explained hereinafter. The 1938 State Applications No. 9364, 9366, 9367, and 9368, assigned to the United States, were

utilized to augment the direct diversions under the aforesaid
1927 State application, but limited to the face value of the
application. The requirement for the Contra Costa Canal, as
both the assumed 1927 and 1938 rights of the United States were
taken under a municipal and industrial demand schedule with a
maximum value of 350 second-feet in July and with lesser values
in other months. Variable assumptions as to demands under
assumed rights of the United States are discussed subsequently.

The basic difference between studies of the "A" and
"B" Series is that under the "A" Series all water rights in
Priority Group 1 were assumed to be satisfied in geographical
order proceeding downstream without regard to any possible
prior status of assumed riparian rights, while under the "B"
Series, assumed riparian rights within that priority group
were assumed to be satisfied before any appropriative rights
regardless of location in the service area. Studies of the
"C" Series differed from those of the "A" and "B" Series in
that all assumed rights were taken as being satisfied in chrono-
logical order in accordance with their priorities. The salient
assumptions and computation procedures that differ among the
studies are described as follows:

"A" Series - Assumed local water rights within
Priority Groups 1, 3, and 5 were assumed to be satis-
fied to the extent of available unregulated modified
natural flows along the River and in the Delta in geo-
graphical order proceeding downstream from Redding,
without regard to priorities in each group, and with

credit being given for return flows from the estimated diversions under these assumed rights. The full face values of local water rights shown in Tables 1 through 4 of Appendix D were assumed in each study except that 70% of historical 1955 Delta Uplands diversions were taken as pre-1927 water rights and 30% of such diversions were taken as post-1938 water rights. These percentages were based upon a cursory examination of the 1955 diversion records and upon information as to water rights under which such diversions were made. Salinity control requirements of 3,300 second-feet were assumed to have a status analogous to a riparian right.

Study A-1 - The requirement for the Delta-Mendota Canal was assumed to be a constant demand of 4,600 second-feet under both 1927 and 1938 assumed rights of the United States. Municipal and industrial requirements of the United States in the Delta under State Application No. 9363 (made in 1938) were assumed to be 100 second-feet.

Study A-2 - The requirement for the Delta-Mendota Canal, under assumed 1927 rights of the United States, was taken on an irrigation demand schedule, with a maximum value of 4,600 second-feet in July and with lesser values in other months. The differences between the irrigation demand and a constant demand schedule were taken as being made up under assumed 1938 rights of the

United States. Municipal and industrial requirements of the United States in the Delta under State Application No. 9363 were assumed to be 1000 second-feet.

Study A-2 (Modified) - Assumptions and procedures were the same as in Study A-2 except that certain other State filings on the Feather, Yuba, Bear, American, Stanislaus, and San Joaquin Rivers, as listed in Table 5 of Appendix D, were assumed to share the water available for Priority Group 2 with assumed rights of the United States. 1951 State applications on the Feather River were assumed to be satisfied after assumed 1954 local water rights because appropriations between 1951 and 1954 were small.

"B" Series - Within Priority Group 1, rights of assumed physically riparian lands above Sacramento and in the Delta Lowlands and salinity control requirements, when assumed to have a status analogous to riparian rights, were taken as being satisfied before any assumed appropriative or "other" water rights. The remaining assumed local appropriative and "other" water rights within Priority Groups 1, 3, and 5, were assumed to be satisfied in geographical order proceeding downstream from Redding without regard to priorities in each group. The full face values of local water rights shown in Tables 1 through 4 of Appendix D were assumed in each study except that 70% of

historical 1955 Delta Uplands diversions were taken on pre-1927 rights and 30% of such diversions were taken on post-1938 rights.

Studies B-1, B-2, and B-2 (Modified) - Assumptions were the same with respect to assumed rights of the United States and other State filings as in corresponding studies of the "A" Series. Salinity control requirements of 3,300 second-feet were assumed to have a status analogous to a riparian right.

Study B-3 - The requirements for the Delta-Mendota Canal, under assumed 1927 rights of the United States, were taken on an irrigation demand schedule with a maximum value of 4,600 second-feet. The differences between the irrigation demand and a constant demand of 4,600 second-feet were taken as being made up under assumed 1938 rights of the United States. Municipal and industrial requirements of the United States in the Delta under State Application No. 9363 were assumed to be 1,000 second-feet. A salinity control requirement of 2,000 second-feet was assumed to have a status analogous to a riparian right.

Study B-4 - Assumptions and procedures were the same as for Study B-3 except that salinity control requirements of 3,300 second-feet were assumed to have a status analogous to a post-1954 appropriative water right.

"C" Series - Rights of assumed physically riparian lands above Sacramento and in the Delta Lowlands and salinity control requirements, when assumed to have a status analogous to a riparian right, were satisfied before any assumed appropriative or "other" water rights. Following this all assumed local appropriative and "other" water rights and assumed rights of the United States were taken as being satisfied in chronological order of priority regardless of location along the Sacramento River and in the Delta Uplands. The full face values of local water rights shown in Tables 1 through 4 of Appendix D, including those for the Delta Uplands, were assumed in each study. In these studies the degrees of satisfaction of assumed riparian and appropriative water rights of each of 26 major water users along the Sacramento River and in the Delta Uplands were estimated. The following are the differences between Studies C-1 and C-2:

Study C-1 - Assumptions were the same with respect to assumed rights of the United States as in Studies A-1 and B-1. Salinity Control requirements of 3,300 second-feet were assumed to have a status analogous to a riparian right.

Study C-2 - Assumptions were the same with respect to assumed rights of the United States as in Studies B-3 and B-4. Salinity control requirements of 3,300 second-feet were assumed to have a status analogous to a post-1954 appropriative water right.

Table 28 presents a summary of the important results of the aforesaid ten studies that pertain to yields of assumed water rights of the local water users and of the United States and to deficiencies and supplemental water requirements relating to assumed rights of the local water users. It is to be noted that deficiencies computed for studies of the "A" and "B" Series are the differences between estimated yields of the respective assumed rights and the 1954-55 level of diversions. Similarly supplemental water requirements under studies of the "A" and "B" Series are the net amounts of water required to firm the yields of the respective assumed water rights to the 1954-55 level of diversions, with credit being given for return flows from use of such supplemental water supplies. Only deficiencies were computed for studies of the "C" Series, and those refer to the differences between yields of assumed water rights and the face values of those rights. These deficiencies were used to compute parameters, or factors, to derive illustrative examples of allocations of responsibility for supplemental water requirements, estimated in the "A" and "B" Series, among major local water users.

Conclusions

The following conclusions have been reached as a result of the analyses of data and information pertaining to water supplies, water use, and water rights along the Sacramento River, in the Sacramento-San Joaquin Delta, and on certain tributaries thereof, which are described in this report.

1. The total of face values of all local water rights assumed for studies of the "A" and "B" Series was 4,044,000 acre-feet during the irrigation season.

2. The total 1954-55 level of local diversions along the Sacramento River and in the Delta was about 3,532,000 acre-feet during the irrigation season excluding water required for salinity control.

3. Studies of the "A" Series indicate that the 31-year-average-irrigation-season yields of all assumed local water rights for beneficial use other than salinity control would have been about 3,200,000 acre-feet, with salinity control assumed to have a status analogous to a riparian right to available flows up to a maximum of 3,300 second-feet. Estimated yields of all assumed local water rights under the three studies of the "A" Series do not differ greatly from one another because of the large percentage of such rights which were assumed to have a pre-1927 priority and because variations in water-right assumptions affect only water rights of 1927 and later priorities.

4. Studies of the "B" Series indicate that the 31-year-average-irrigation-season yields of all assumed local water rights would have been about 2,700,000 acre-feet, with salinity control requirements up to a maximum of 3,300 second-feet assumed to have a status analogous to a riparian right; about 2,850,000 acre-feet, with salinity control requirements up to a maximum of 2,000 second-feet assumed to have a status analogous to a riparian right; and about 3,150,000 acre-feet

with salinity control requirements up to a maximum of 3,300 second-feet assumed to have a status analogous to a post-1927 appropriative water right. Estimated yields of all assumed local water rights under the first three studies of the "B" Series do not differ greatly from one another because of the large percentage of such rights which were assumed to have a pre-1927 priority and because variations in water-right assumptions affect only water rights of 1927 and later priorities.

5. Estimated yields of assumed local water rights of pre-1927 priority above Sacramento are greater under the "A" Series than under the "B" Series because such rights in the "A" Series were assumed to be satisfied in geographical order proceeding downstream from Redding, thus leaving the satisfaction of rights in the Delta to last priority within the pre-1927 priority group. Conversely, estimated yields of assumed local water rights of pre-1927 priority in the Delta are greater under the "B" Series than under the "A" Series.

6. Estimated yields of assumed 1927-1938 and post-1938 rights of local water users are small in the months of July through October.

7. The total requirements for salinity control during the irrigation season, April through October, are 1,400,000 acre-feet for a constant outflow from the Delta of 3,300 second-feet and 850,000 acre-feet for a constant outflow of 2,000 acre-feet.

8. Studies of the "A" Series indicate that the 31-year-average-irrigation-season quantities of water available to meet requirements for salinity control up to a maximum of

of 3,300 second-feet, taken as having a status analogous to a riparian right, would have been about 960,000 acre-feet.

9. Studies of the "B" Series indicate that the 31-year-average-irrigation-season quantities of water available to meet requirements for salinity control would have been about 1,160,000 acre-feet with such requirements up to a maximum of 3,300 second-feet assumed to have a status analogous to a riparian right; about 740,000 acre-feet with such requirements up to a maximum of 2,000 second-feet assumed to have a status analogous to a riparian right; and 590,000 acre-feet with such requirements up to a maximum of 3,300 second-feet assumed to have a status analogous to a post-1954 appropriative water right.

10. Assumed irrigation season totals of water rights of the United States under 1927 direct diversion and storage filings and under 1938 direct diversion filings amounted to about 3,550,000 acre-feet for Studies A-1 and B-1 and about 3,800,000 acre-feet for all other studies of the "A" and "B" Series.

11. Total 31-year-average-irrigation-season yields of all assumed rights of the United States would have been about 1,500,000 acre-feet for Studies A-1, A-2 (Modified), B-1, and B-2 (Modified) with salinity control up to a maximum requirement of 3,300 second-feet assumed to have a status analogous to a riparian right. Lower yields than would normally be expected for greater assumed rights in the modified studies are caused by part of the available supply under these studies being required for State filings on the

other streams mentioned in this chapter under the heading, "Summary".

12. Total 31-year-average-irrigation-season yields of all assumed rights of the United States under Studies A-2 and B-2 would have been about 1,700,000 acre-feet with salinity control requirements up to a maximum of 3,300 second-feet assumed to have a status analogous to a riparian right. Greater estimated yields under these studies than under Studies A-1 and B-1, respectively, are due to the assumption of greater municipal and industrial demands under the 1938 direct diversion rights in the Delta.

13. Total 31-year-average-irrigation-season yields of all assumed rights of the United States under Study B-3 would have been about 1,800,000 acre-feet, with salinity control requirements up to a maximum of 2,000 second-feet assumed to have a status analogous to a riparian right.

14. Total 31-year-average-irrigation-season yields of all assumed rights of the United States under Study B-4 would have been about 2,100,000 acre-feet, with salinity control requirements up to a maximum of 3,300 second-feet assumed to have a status analogous to a post-1954 appropriative water right.

15. Study C-1, with salinity control requirements up to a maximum of 3,300 second-feet assumed to have a status analogous to a riparian right, indicates that the total 31-year-average-irrigation-season yield of assumed riparian and appropriative water rights of 26 major entities along the Sacramento River above Sacramento and in the Delta Uplands

would have been about 1,330,000 acre-feet; that the average yield for the Delta Lowlands would have been about 1,040,000 acre-feet; that the average yield for water users other than the foregoing would have been about 420,000 acre-feet; and that the total average yield of all assumed local water rights would have been about 2,790,000 acre-feet.

16. Study C-2, with salinity control requirements up to a maximum of 3,300 second-feet assumed to have a status analogous to a post-1954 appropriative water right, indicates that the total 31-year-average-irrigation-season yield of assumed riparian and appropriative water rights of 26 major entities along the Sacramento River above Sacramento and in the Delta Uplands would have been about 1,750,000 acre-feet; that the average yield for the Delta Lowlands would have been about 1,040,000 acre-feet; that the average yield for other water users not considered in detail would have been about 460,000 acre-feet; and that the total average yield of all assumed local water rights would have been about 3,250,000 acre-feet. The greater yields under Study C-2 than under Study C-1 are due to differences of assumptions regarding salinity control.

17. The average irrigation deficiency, or the total 31-year-average-irrigation-season difference between the yields of all assumed local water rights and the 1954 level of diversions north of Sacramento and the 1955 level of water utilization in the Delta, would have been about 480,000 acre-feet as estimated by studies of the "A" Series

and 990,000 acre-feet as estimated by the first three studies of the "B" Series, with salinity control requirements up to a maximum of 3,300 second-feet assumed to have a status analogous to a riparian right. The average irrigation deficiency would have been about 830,000 acre-feet as estimated by Study B-3, with salinity control requirements up to a maximum of 2,000 second-feet assumed to have a status analogous to a riparian right. The average irrigation deficiency would have been about 560,000 acre-feet as estimated by Study B-4 with salinity control requirements up to a maximum of 3,300 second-feet assumed to have a status analogous to a post-1954 appropriative water right.

18. The average salinity control deficiency, or the total 31-year-average-irrigation-season difference between the salinity control requirements and the quantities of water available to meet those requirements, would have been about 430,000 acre-feet as estimated by studies of the "A" Series and 240,000 acre-feet as estimated by the first three studies of the "B" Series, with salinity control requirements up to a maximum of 3,300 second-feet assumed to have a status analogous to a riparian right. The average salinity control deficiency would have been about 110,000 acre-feet, as estimated by Study B-3, with salinity control requirements up to a maximum of 2,000 second-feet assumed to have a status analogous to a riparian water right; and about 780,000 acre-feet as estimated by Study B-4, with salinity control requirements up to a maximum of 3,300 second-feet assumed to have a status analogous to a post-1954 appropriative water right.

19. The average irrigation deficiencies for the Series were taken as the 31-year-average-irrigation-season differences between yields of assumed water rights and the values of such rights. Study C-1, with salinity control requirements up to a maximum of 3,300 second-feet assumed to have a status analogous to a riparian right, indicates that the average irrigation deficiency for 26 major entities along the Sacramento River above Sacramento and in the Delta Uplands would have been about 1,100,000 acre-feet; that the average irrigation deficiency for the Delta Lowlands would have been about 16,000 acre-feet; that the average irrigation deficiency for water users other than the foregoing would have been about 410,000 acre-feet; and that the total average irrigation deficiency for all local water users would have been about 1,530,000 acre-feet. The value of 1,530,000 acre-feet is greater than the corresponding irrigation deficiency for Study B-1, amounting to about 990,000 acre-feet, because the former is based upon the full assumed rights of local water users and the latter is based upon the lesser 1954-55 level of diversion.

20. Study C-2, with salinity control requirements up to a maximum of 3,300 second-feet assumed to have a status analogous to a post-1954 appropriative water right, indicates that the average irrigation deficiency for the 26 major entities along the Sacramento River above Sacramento and in the Delta Uplands would have been about 690,000 acre-feet; that average irrigation deficiency for the Delta Lowlands would have been about 16,000 acre-feet; that the average irrigation deficiency

for water users other than the foregoing would have been about 370,000 acre-feet; and that the total average irrigation water deficiency for all local water users would have been about 1,070,000 acre-feet. The value of 1,070,000 acre-feet is greater than the corresponding figure for Study B-4, amounting to about 560,000 acre-feet, because the former is based upon the full assumed rights of local water users and the latter is based upon the lesser 1954-55 level of diversions.

21. The average supplemental irrigation water requirements, or those quantities of water needed to firm the 31-year-average-irrigation season yields of all assumed rights of local water users to the 1954-55 level of diversions, would have been about 420,000 acre-feet as estimated by studies of the "A" Series and about 670,000 acre-feet as estimated by the first three studies of the "B" Series, with salinity control requirements up to a maximum of 3,300 second-feet, assumed to have a status analogous to a riparian right. The average supplemental irrigation water requirement would have been about 580,000 acre-feet as estimated by Study B-3, with salinity control requirements up to a maximum of 2,000 second-feet assumed to have a status analogous to a riparian right. The average supplemental irrigation water requirement would have been about 410,000 acre-feet, as estimated by Study B-4, with salinity control requirements up to a maximum of 3,300 second-feet assumed to have a status analogous to a post-1954 appropriative water right.

22. The 31-year-average-irrigation-season-supplemental water requirements for salinity control would have been about 430,000 acre-feet as estimated by studies of the "A" Series and about 220,000 acre-feet as estimated by the first three studies of the "B" Series, with salinity control requirements up to a maximum of 3,300 second-feet assumed to have a status analogous to a riparian right. The average supplemental water requirement for salinity control would have been about 102,000 acre-feet, as estimated by Study B-3, with salinity control requirements up to a maximum of 2,000 second-feet assumed to have a status analogous to a riparian right; and about 780,000 acre-feet as estimated by Study B-4, with salinity control requirements up to a maximum of 3,300 second-feet assumed to have a status analogous to a post-1954 appropriative water right.

23. Total supplemental water requirements for irrigation and salinity control under each study would have been about 2.5 times the foregoing 31-year-average values during the critically dry year of 1931 and an average of about 1.4 times such values during the critically dry period from 1928 through 1934.

24. The results of illustrative allocations among individual water users of total supplemental irrigation water requirements are shown in Table 27. These were derived by applying allocation parameter values based upon deficiency information from the "C" Series to supplemental water requirements as estimated by several studies of the "A" and "B" Series. That table indicates for most of the 26 major entities

relatively small differences between allocations derived by using parameters based upon deficiency information from C-1 and those based upon C-2 information. In some cases the C-1 parameters result in a greater allocation of responsibility for supplemental water to a given water diverter and in other cases the C-2 parameters result in the greater allocated responsibility. However, results for the Glenn-Colusa Irrigation District indicate a substantial reduction of the allocated responsibility based upon C-2 parameters as compared to the responsibility based upon C-1 parameters. The result for all other appropriators not considered in detail indicate a substantial increase of the allocated responsibility based upon the C-2 parameters as compared to the responsibility based upon C-1 parameters.

25. Other illustrative allocations of responsibility for supplemental water might be made by applying the parameter values given in this report, or similar values, to results of studies of the "A" and "B" Series not shown on Table 27 or to results of any other similar studies.

26. The illustrative allocations of responsibility for supplemental irrigation water, mentioned above, are for average conditions during the period 1924 through 1954. It is believed that this allocation approach with modification might also be used under operating conditions if it is decided to base the annual payment for supplemental water upon anticipated water supply conditions and conditions of demand occurring during each specific year.

Recommendations

It is recommended:

1. That representatives of the water user associations study in detail the results contained in this report, and if necessary the detailed computations on file with the Department of Water Resources, in order to evaluate the conclusions and the adequacy and soundness of the underlying assumptions and computation procedures.

2. That representatives of the Bureau of Reclamation, the Department of Water Resources, and all interested water user organizations meet as soon as possible to discuss the adequacy of the findings contained herein for negotiations to follow and, if necessary, to recommend certain minimum additional studies in order that the essential data may be made available.

3. That negotiations among representatives of the interested parties be commenced as soon as possible on a continuous basis.

4. That the various problems facing the parties in reaching and negotiating an agreement on water rights and on provision of a supplemental water supply to the water users be identified and that special permanent committees be established to determine ways and means of solving each problem including possible compromise proposals.

5. That water users begin study of the types of district, districts, or other legally constituted entities necessary to negotiate and enter into an agreement and that

steps necessary to accomplish the formation be initiated
suant to terms of the Memorandum of Understanding of
cluded as Appendix A to this report.